

What is claimed is:

1. A method for making a glass-ceramic, the method comprising heat-treating glass to convert at least a portion of the glass to crystalline ceramic and provide glass-ceramic, the glass comprising at least 35 percent by weight Al_2O_3 , based on the total weight of the glass, REO, at least one of ZrO_2 or HfO_2 , and at least one of Nb_2O_5 or Ta_2O_5 , wherein the glass contains not more than 10 percent by weight collectively As_2O_3 , B_2O_3 , GeO_2 , P_2O_5 , SiO_2 , TeO_2 , and V_2O_5 , based on the total weight of the glass, and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of at least one of crystalline ZrO_2 or crystalline HfO_2 formation from the glass as compared to a comparative glass-ceramic made by heat-treating, in the same manner, the same glass free of Nb_2O_5 and Ta_2O_5 .
2. The method according to claim 1, wherein the glass comprises ZrO_2 , and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass as compared to the comparative glass-ceramic.
3. The method according to claim 2, wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 1.5 as compared to the comparative glass-ceramic.
4. The method according to claim 2, wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 2 as compared to the comparative glass-ceramic.
5. The method according to claim 2, wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 3 as compared to the comparative glass-ceramic.

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6. The method according to claim 2, wherein the glass comprises at least 50 percent by weight Al_2O_3 , based on the total weight of the glass.

7. The method according to claim 2, wherein the glass comprises at least 15 percent by weight ZrO_2 , based on the total weight of the glass.

8. The method according to claim 2, wherein the glass comprises at least 20 percent by weight ZrO_2 , based on the total weight of the glass.

9. The method according to claim 2, wherein the glass comprises at least 5 percent by weight of at least one of Nb_2O_5 or Ta_2O_5 , based on the total weight of the glass.

10. The method according to claim 9, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

11. The method according to claim 1, wherein the glass comprises at least 50 percent by weight Al_2O_3 , at least 30 percent by weight REO, and at least 10 percent by weight ZrO_2 .

12. The method according to claim 1, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

13. The method according to claim 1, wherein the glass comprises at least 15 percent by weight ZrO_2 , based on the total weight of the glass.

14. The method according to claim 1, wherein the glass-ceramic has an average hardness of at least 15 GPa.

15. The method according to claim 1, further crushing the glass-ceramic to provide abrasive particles.

16. The method according to claim 15, further comprises grading the abrasive particles to provide a plurality of particles having a specified nominal grade.

17. The method according to claim 15 further comprises incorporating the
5 abrasive particles into an abrasive article.

18. The method according to claim 17, wherein the abrasive article is a bonded abrasive article, a non-woven abrasive article, or a coated abrasive article.

10 19. The method according to claim 1, wherein the glass-ceramic has an average hardness of at least 16 GPa.

20. The method according to claim 1, wherein the glass-ceramic has an average hardness of at least 17 GPa.

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21. The method according to claim 1, wherein the glass-ceramic has an average hardness of at least 18 GPa.

22. The method according to claim 1, wherein the glass-ceramic has an average
20 hardness of at least 19 GPa.

23. A method for making a glass-ceramic, the method comprising heat-treating ceramic comprising glass to convert at least a portion of the glass to crystalline ceramic and provide glass-ceramic, the glass comprising at least 35 percent by weight Al_2O_3 , based on the
25 total weight of the glass, REO, at least one of ZrO_2 or HfO_2 , and at least one of Nb_2O_5 or Ta_2O_5 , wherein the glass contains not more than 10 percent by weight collectively As_2O_3 , B_2O_3 , GeO_2 , P_2O_5 , SiO_2 , TeO_2 , and V_2O_5 , based on the total weight of the glass, and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of at least one of crystalline ZrO_2 or crystalline HfO_2 formation from the glass as compared to a
30 comparative glass-ceramic made by heat-treating, in the same manner, the same glass free of Nb_2O_5 and Ta_2O_5 .

24. The method according to claim 23, wherein the glass comprises ZrO_2 , and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass as compared to the comparative glass-ceramic.

25. The method according to claim 24, wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 2 as compared to the comparative glass-ceramic.

26. The method according to claim 24, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

27. The method according to claim 24, further comprising crushing the glass-ceramic to provide abrasive particles.

28. The method according to claim 27, further comprises grading the abrasive particles to provide a plurality of particles having a specified nominal grade.

29. A method for making an abrasive article, wherein the method according to claim 27 further comprises incorporating the abrasive particles into an abrasive article.

30. A method for making abrasive particles, the method comprising heat-treating glass particles to convert at least a portion of the glass to crystalline ceramic and provide glass-ceramic and the abrasive particles, the glass comprising at least 35 percent by weight Al_2O_3 , based on the total weight of the glass, REO, at least one of ZrO_2 or HfO_2 , and at least one of Nb_2O_5 or Ta_2O_5 , wherein the glass contains not more than 10 percent by weight collectively As_2O_3 , B_2O_3 , GeO_2 , P_2O_5 , SiO_2 , TeO_2 , and V_2O_5 , based on the total weight of the glass, and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of at least one of crystalline ZrO_2 or crystalline HfO_2 formation from the

glass as compared to a comparative glass-ceramic made by heat-treating, in the same manner, the same glass free of Nb_2O_5 and Ta_2O_5 .

31. The method according to claim 30, wherein the glass comprises ZrO_2 , and
5 wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass as compared to the comparative glass-ceramic.

32. The method according to claim 31, wherein the at least one of Nb_2O_5 or Ta_2O_5
10 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 1.5 as compared to the comparative glass-ceramic.

33. The method according to claim 31, wherein the at least one of Nb_2O_5 or Ta_2O_5
15 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 2 as compared to the comparative glass-ceramic.

34. The method according to claim 31, wherein the at least one of Nb_2O_5 or Ta_2O_5
is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 3 as compared to the comparative glass-ceramic.

20 35. The method according to claim 31, wherein the glass comprises at least 50 percent by weight Al_2O_3 , based on the total weight of the glass.

25 36. The method according to claim 31, wherein the glass comprises at least 15 percent by weight ZrO_2 , based on the total weight of the glass.

37. The method according to claim 31, wherein the glass comprises at least 20 percent by weight ZrO_2 , based on the total weight of the glass.

30 38. The method according to claim 31, wherein the glass comprises at least 5 percent by weight of at least one of Nb_2O_5 or Ta_2O_5 , based on the total weight of the glass.

39. The method according to claim 38, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

5 40. The method according to claim 31, wherein the glass comprises at least 50 percent by weight Al_2O_3 , at least 30 percent by weight REO, and at least 10 percent by weight ZrO_2 .

10 41. The method according to claim 31, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

42. The method according to claim 31, wherein the glass comprises at least 15 percent by weight ZrO_2 , based on the total weight of the glass.

15 43. The method according to claim 31, further comprises grading the abrasive particles to provide a plurality of particles having a specified nominal grade.

44. The method according to claim 31 further comprises incorporating the abrasive particles into an abrasive article.

20 45. The method according to claim 44, wherein the abrasive article is a bonded abrasive article, a non-woven abrasive article, or a coated abrasive article.

25 46. The method according to claim 31, wherein the glass-ceramic has an average hardness of at least 16 GPa.

47. The method according to claim 31, wherein the glass-ceramic has an average hardness of at least 17 GPa.

30 48. The method according to claim 31, wherein the glass-ceramic has an average hardness of at least 18 GPa.

49. The method according to claim 31, wherein the glass-ceramic has an average hardness of at least 19 GPa.

50. A method for making abrasive particles, the method comprising heat-treating particles comprising glass to convert at least a portion of the glass to crystalline ceramic and provide glass-ceramic and the abrasive particles, the glass comprising at least 35 percent by weight Al_2O_3 , based on the total weight of the glass, REO, at least one of ZrO_2 or HfO_2 , and at least one of Nb_2O_5 or Ta_2O_5 , wherein the glass contains not more than 10 percent by weight collectively As_2O_3 , B_2O_3 , GeO_2 , P_2O_5 , SiO_2 , TeO_2 , and V_2O_5 , based on the total weight of the glass, and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of at least one of crystalline ZrO_2 or crystalline HfO_2 formation from the glass as compared to a comparative glass-ceramic made by heat-treating, in the same manner, the same glass free of Nb_2O_5 and Ta_2O_5 .

51. The method according to claim 50, wherein the glass comprises ZrO_2 , and wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass as compared to the comparative glass-ceramic.

52. The method according to claim 51, wherein the at least one of Nb_2O_5 or Ta_2O_5 is present in an amount sufficient to increase the rate of crystalline ZrO_2 formation from the glass by at least a factor of 2 as compared to the comparative glass-ceramic.

53. The method according to claim 51, wherein the REO is at least one of Gd_2O_3 , La_2O_3 , or Nd_2O_3 .

54. The method according to claim 51, further comprises grading the abrasive particles to provide a plurality of particles having a specified nominal grade.

55. A method for making an abrasive article, wherein the method according to claim 51 further comprises incorporating the ceramic abrasive particles into an abrasive article.